What is the effect of dietary intake of MUFA on health and intermediate health outcomes?

Conclusion

Strong evidence indicates that dietary monounsaturated fatty acids (MUFA) are associated with improved blood lipids related to both cardiovascular disease (CVD) and type 2 diabetes (T2D), when they are a replacement for dietary saturated fatty acids (SFA). The evidence shows that five percent energy replacement of SFA with MUFA decreases intermediate markers and the risk of CVD and T2D in healthy adults and improves insulin responsiveness in insulin resistant and T2D subjects.

Grade: Strong

Overall strength of the available supporting evidence: Strong; Moderate; Limited; Expert Opinion Only; Grade not assignable For additional information regarding how to interpret grades, click here.

Evidence Summary Overview

Thirteen studies published since 2004 and conducted in the US, Europe and Australia were reviewed to determine the effect of monounsaturated fat (MUFA) on health outcomes. These included one methodologically strong meta-analysis evaluating 11 prospective cohort studies (Jakobsen, 2009) and 11 randomized controlled trials (RCTs) ranging from 14 to 162 subjects, including six methodologically strong studies (Appel, 2005; Berglund, 2007; Due, 2008; Lopez, 2008; Thijssen and Mensink, 2005; and Thijssen, 2005) and five methodologically neutral studies (Allman-Farinelli, 2005; Binkoski, 2005; Clifton, 2004; Paniagua, 2007; and Rasmussen, 2006). The reviewed studies also included one methodologically strong prospective cohort study of 5,672 subjects from the Nurses' Health Study who reported a diagnosis of type 2 diabetes (T2D) (Tanasescu, 2004).

Overall, MUFA replacing saturated fat (SFA) in the diet as percent of energy leads to a decrease in low-density lipoprotein cholesterol (LDL-C) (Allman-Farinelli, 2005; Appel, 2005; Berglund, 2007), a decrease in serum triglycerides (TG) (Allman-Farinelli, 2005), a decrease in markers of inflammation (Allman-Farinelli, 2005), and a decrease in cardiovascular disease (CVD) risk (Appel, 2005; Rasmussen, 2006). Increasing MUFA intake, rather than replacing SFA with MUFA, also leads to a decrease in total cholesterol (TC) (Haban, 2004), LDL-C (Haban, 2004), LDL-C to high-density lipoprotein cholesterol (HDL-C) ratio (Due, 2008), serum TG (Brunerova, 2007), inflammatory markers (Brunerova, 2007) and fasting insulin and Homeostasis Model Assessment-Insulin Resistance (HOMA-IR) scores (Brunerova, 2007; Due, 2008). However, Clifton et al, (2004) found a greater decrease in TC and HDL-C in women who consumed a very low-fat diet, compared with a high MUFA diet and no difference in the LDL:HDL ratio between the two diets (Clifton, 2004). Replacing SFA with MUFA, compared to replacement with carbohydrates (CHO), decreased serum TG (Appel, 2005) and increased HDL-C (Appel, 2005; Berglund, 2007). Lastly, a prospective cohort study involving a T2D subpopulation within the Nurses' Health Study found that replacing 5% energy from SFA with equivalent energy from MUFA was associated with a 27% lower risk of CVD. The authors conclude that replacing SFA with MUFA may be more protective against CVD than replacement with CHO (Tanasescu, 2004).

Comparing substitution of SFA with MUFA vs. polyunsaturated fat (PUFA) showed a greater decrease in TC and LDL-C with PUFA substitution (Binkoski, 2005). Furthermore, a pooled analysis of 11 prospective cohort studies showed that risk of coronary events and coronary death was lowest with 5% energy substitution of SFA with PUFA; PUFA substitution resulted in the greatest decrease, with MUFA showing somewhat less, and CHO showing the least improvement when substituted for SFA (Jakobsen, 2009). In a comparison of individual fatty acids, oleic acid was no different than stearic or linoleic acid in its effect on measures of serum lipids or lipoproteins and markers of inflammation (Thijssen and Mensink, 2005; Thijssen, 2005).

Evidence Summary Paragraphs

Allman-Farinelli et al, 2005 (neutral quality) This was a randomized, extra-period crossover trial, conducted in Australia. The study compared the effect of a SFA-rich diet with a MUFA-rich diet on the concentrations of factor VII coagulant activity factor, fibrinogen, plasminogen, activator inhibitor-1 and blood lipids. Subjects consumed either the SFA-rich diet (20.8% energy as fat) for five weeks and crossed over to the MUFA-rich diet (20.3% energy as fat) for 10 weeks or the opposite diets with no washout period between diets. Fifteen of the 18 initial subjects (five males, 10 females; aged 35-69 years) completed the study. Subjects completed three-day food diaries on two occasions during each intervention. Weight was maintained throughout the study. Dietary compliance was confirmed by a significant increase in both plasma phospholipids and neutral lipid oleic acid ($P<0.0001$) on the MUFA diet. Factor VIIc was lower (97±1%) on the MUFA diet ($P<0.05$) compared to the SFA diet (99±1).Low-density lipoprotein cholesterol (3.47±0.06mmol per L) was lower ($P<0.001$) compared to SFA (4.01±0.07mmol per L) and TG levels were also lower ($P<0.01$) on the MUFA -rich diet (144.0±4.6mmol per L) compared to the SFA diet (145.1±4.9mmol per L). There were no differences between diets for fibrinogen and insulin concentrations or plasminogen activator inhibitor-1 activity.

Appel et al, 2005 (positive quality) This was the Omni Heart randomized, three-period crossover trial conducted in the US. The study compared the effect of three reduced SFA, on blood pressure (BP) and serum lipids in 191 healthy adults with stage I hypertension (HTN) or pre-hypertension (PHTN). The three six-week interventions included a diet rich in CHO, a diet rich in protein (about half from plant sources) and a diet rich in unsaturated fat (predominantly MUFA); all were reduced in SFA, cholesterol and sodium, and rich in fruits, vegetables, fiber, potassium and other minerals at the recommended levels. One hundred sixty one subjects were included in this analysis (45% women, mean age 53.6±10.9 years). Blood pressure, LDL-C and estimated CHD risk were lower on each diet compared to baseline. Compared with the CHO-rich diet, the unsaturated fat diet decreased systolic blood pressure (SBP) by 1.3mmHg ($P=0.005$) and by 2.9mmHg among those with HTN ($P=0.02$), had no effect on LDL-C, increased HDL-C by 1.1mg per dL (0.03mmol per L, $P=0.03$) and lowered TG by 9.6mg per dL (0.11mmol per L, $P=0.02$).

Berglund et al, 2007 (positive quality) This was a randomized crossover trial conducted in the US. The study compared MUFA with CHO as a replacement for SFA in subjects with a high metabolic risk profile. Three diets were fed in a double-blind, three-way crossover with each lasting seven-weeks with a rest period of four to six weeks between each intervention. The three diets reflected the typical pattern of the US population. Two were modified to replace 7% of energy from SFA with either CHO (primarily complex) on the CHO-replacement diet or with MUFA on the MUFA-replacement diet. All food was provided except for a self-selected meal [following the NCEP Step I guidelines] on Saturday evenings. Blood samples were drawn at weeks five, six and seven of each intervention. Eighty five of the initial 110 subjects completed all three interventions (33 females, 52 males and mean age 35.5±9.2 years, range 21-61 years). Relative to the average American diet, LDL-C was lower with both the CHO-replacement diet (-7.0%) and MUFA-replacement diet (-6.3%), whereas the difference in HDL-C was smaller during the MUFA-replacement diet (-4.3%) than during the CHO-replacement diet (-7.2%). Lipoprotein (a) concentrations increased with both the CHO-replacement diet (20%) and MUFA-replacement diet (11%) relative to the average American diet.

Binkoski et al, 2005 (neutral quality) This was a randomized crossover trial conducted in the US. The study evaluated the effect of a trans fat-free MUFA-rich vegetable oil on lipid and lipoprotein levels and measures of oxidative stress. Thirty one subjects (12 men, 19 women and 25-64 years of age) with moderate hypercholesterolemia enrolled and completed the trial. Subjects were randomized to one of three, four-week dietary interventions with a two-week washout period. Two of the experimental diets provided 30% fat, with olive oil or NuSun sunflower oil contributing one-half of the fat (8.3% vs. 7.9%SFA, 17.2% vs. 14.2% MUFA, and 4.3% vs. 7.7% PUFA, respectively). NuSun is mid-oleic sunflower oil developed by standard hybrid breeding that contains a similar proportion of and substantially greater proportion PUFAs and less SFA compared than olive oil. The third diet was an average American diet (AAD) (34% fat, 11.2% SFA, 14.9% MUFA and 7.8% PUFA). The test fats were incorporated in sauces, spreads, baked goods, granola and salad dressings. The NuSun sunflower oil diet significantly reduced total and LDL-C levels, as well as apolipoprotein A-1 levels compared with the average American diet ($P<0.001$, $P=0.0006$ and $P=0.0004$, respectively). The olive oil diet had no effect compared with the AAD. The experimental diets had no effect on TG levels, rate of oxidation, total dienes, lipid hydroperoxides or alpha-tocopherol ($P>0.05$).

Clifton et al, 2004 (neutral quality) This was an RCT with parallel design. This study investigated the effects of a very low-fat diet (VLF) vs, a high MUFA (H-MUFA) weight loss diet on body fat distribution, weight and lipid profile in overweight women without T2D [N=62, body mass index (BMI)>27kg/m^2].

Subjects were matched by age and BMI and randomized to consume one of two 6,000kJ diets: 35% energy from fat, 20% energy from MUFA) (H-MUFA diet) or 12% energy from fat, 4% energy from MUFA (VLF diet) for 12 weeks. Weight loss (9.5±2.4 vs. 9.4±3.4kg, VLF vs. H-MUFA) and total fat loss (6.1±2.4 vs. 6.3±2.7kg, VLF vs. H-MUFA) did not differ in the groups. There was a diet x menopausal status interaction in lean mass changes (P=0.005) such that in premenopausal women, H-MUFA produced a lower loss of lean mass than the low-fat diet (0.4±2.3 vs. 2.9±2.7kg, P=0.006) with the opposite, but NS effect seen in postmenopausal women. There was a greater decrease in total plasma cholesterol in women who consumed VLF compared with those who consumed H-MUFA (0.82±0.0.51 vs. 0.50±0.48mmol per L, P<0.001 for time, P<0.05 for diet effect). This was also true for the change in HDL-C (0.18±0.23 vs. 0.04±0.19mmol per L, VLF and H-MUFA, respectively, P<0.001 for time, P<0.05 for diet effect). The LDL/HDL ratio was reduced in both groups with no effect of diet (0.16±0.51 vs. 0.16±0.45, VLF and H-MUFA, respectively, P<0.05). Authors conclude that weight, total fat mass and regional fat mass loss did not differ in the two groups of women, but there was an apparent preservation of lean mass in premenopausal women consuming H-MUFA.

Due et al, 2008 (positive quality) This was an RCT with parallel design to compare the effect on weight-loss maintenance and change in CVD and diabetic risk factors of three diets (Willett's new Healthy Eating Pyramid, the Official Nordic Dietary Guidelines and the average Danish diet) in a six-month controlled dietary maintenance program, for 154 non-diabeticoverweight or obese subjects [mean±SD *BMI*): 31.5±2.6kg/m^2] men (N=55) and women (N=76) aged 28.2±4.8 years in Denmark. Subjects were randomly assigned to a diet providing a moderate amount of fat (35-45% of energy) and >20% of fat asMUFA (MUFA diet; N=54), to a low-fat (20-30% of energy) diet (LF diet; N=51), or to a control diet (35% of energy as fat; N=26). Protein constituted 10-20% of energy in all three diets. All foods were provided from a purpose-built supermarket. The attrition rate was higher for MUFA (28%) group than for the LF group (16%) and control group (8%) (MUFA compared with control: P<0.05). All groups regained weight (MUFA: 2.5±0.7kg; LF: 2.2±0.7kg; and control: 3.8±0.8kg;NS). Body fat regain was lower in the LF (0.6±0.6%) and MUFA (1.6±0.6%) groups than in the control group (2.6±0.5%, P<0.05). In the MUFA group, fasting insulin decreased by 2.6±3.5 pmol per L, the HOMA-IR by 0.17±0.13, and the ratio of LDL:HDL by 0.33±0.13; in the LF group, these variables increased by 4.3±3.0pmol per L (P<0.08) and 0.17±0.10 (P<0.05) and decreased by 0.02±0.09 (P=0.005), respectively; and in the control group, increased by 14.0±4.3pmol per L (P<0.001), 0.57±0.17 (P<0.001) and 0.05±0.14 (P=0.036), respectively. Dietary adherence was high on the basis of fatty acid changes in adipose tissue. Diet composition had no major effect on preventing weight regain. Both the LF and MUFA diets produced less body fat regain than did the control diet, and the dropout rate was lowest in the LF diet group. Fasting insulin decreased and the HOMA-IR and ratio of LDL to HDL improved with the MUFA diet.

Jakobsen et al, 2009 (positive quality) This pooled analysis evaluated the associations between energy intake from MUFA, PUFA and CHO replacing energy from SFA to prevent CHD. Data from 11 American and European cohort studies involving 344,696 persons were pooled and analyzed for incident of CHD as outcome measures. During four to 10-year follow-up, there were 5,249 coronary events and 2,155 coronary deaths. The analysis found that for every 5% lower energy intake from SFAs and a concomitant higher energy intake from PUFAs or CHOs, there was a significant inverse association between these energy sources and risk of coronary events, with hazard ratios (HR) as follows for PUFAs: HR: 0.87(95% CI: 0.77, 0.97); HR for coronary deaths= +0.74 (95% CI: 0.61, 0.89) and for CHOs: HR: 1.07 (95% CI: 1.01, 1.14); HR for coronary deaths=0.96 (95% CI: 0.82, 1.13), respectively. There was indication of a positive association between substitution of MUFAs and risk of coronary events (HR: 1.19; 95% CI: 1.00, 1.42), but not risks of coronary deaths. There was also a modest, but significant, association between substitution of CHO and risk of coronary events (HR: 1.07; 95% CI: 1.01, 1.14), but not risk of coronary deaths. There was no effect modification by gender or age. The authors conclude that replacing SFAs with PUFAs rather than MUFAs or CHOs prevents CHD over a wide range of intakes. The country and demographics of subjects not described. The type of CHO in the diet was not taken into account in this analysis (i.e., extent of processing, fiber content, or glycemic index, although discussed).

Lopez et al, 2008 (positive quality) This was a randomized, single-blinded, crossover trial of 14 healthy men in Spain to determine the degree to which unsaturation of dietary fatty acids influences thepostprandial control of insulin secretion and insulin sensitivity. The postprandial response to high-fat meals enriched in SFAs or MUFAs was assessed using mixed meals with common foods. The isocaloric diet interventions included 9% more fat, replacing CHO in the control NCEP diet, and were as follows:

1. NCEP Step I
2. High butter (MUFA:SFA, 0.48:1.0)
3. Refined olive oil (ROO) (MUFA:SFA, 5.43:1.0)
4. High palmitic sunflower oil (HPSO) (MUFA:SFA, 2.42:1.0)
5. Mixture of vegetable and fish oils (VEFO) (MUFA:SFA, 7.08:1.0).

Subjects were normo-triglyceridemic and had normal fasting blood glucose (FBG) and glucose tolerance. Results showed that high fat meals increased the postprandial concentrations of insulin, TG, and free fatty acids (FFAs), and they increased postprandial b-cell activity as assessed by the insulinogenic index (IGI), a surrogate measure of first-phase insulin secretion; IGI/HOMA-IR ratio; AUCinsulin/AUCglucose ratio; and HOMA of b-cell function (HOMA-B). High fat meals also decreased postprandial insulin sensitivity assessed by a glucose and TG tolerance test meal (GTTTM)-determined insulin sensitivity test and the postprandial Belfiore indices for glycemia and bloodFFAs. These effects were significantly improved, in a linear relationship, when MUFAs were substituted for SFAs; subjects became less insulin resistant postprandially as the proportion of MUFAs, compared with SFAs, in dietary fats increased (VEFO>ROO>HPSO>butter). When the early postprandial insulin response was used as a measure of b-cell activity, it decreased as the ratio of MUFA/SFA increased. Overall the findings suggest that b-cell function and insulin sensitivity progressively improve in the postprandial state as the proportion of MUFAs, relative to SFAs, increases in the diet, suggesting that MUFAs moderate the postprandial hyperactivity of the pancreatic b-cell. The underlying mechanism likely involves different insulinotropic potentials of individual FFA (e.g., oleic acid has been reported to elicit half the insulin secretion from b-cells as palmitic or stearic acids).

Paniagua et al, 2007 (neutral quality) This was a randomized crossover study on offspring of obese, T2D patients recruited from diabetic patients' records at primary care centers in Cordoba Spain. Fifty-nine potential subjects were recruited, but 27 subjects either did not meet the inclusion criteria or refused to participate. Qualifying subjects underwent an oral glucose tolerance test (OGTT), after which 11 insulin resistant (IR) subjects (four men, seven women) remained in the study. Subjects had aBMI=25kg/m^2. Subjects were randomly assigned to three groups and underwent three diet periods of 28 days in a crossover design:

1. Diet high in SFA (SAT): Increased 15% energy as SFA
2. Diet high in MUFA (MUFA): Increased 15% energy as MUFA
3. Diet high in CHO: Increased 18% energy as CHO.

Body weight and resting energy expenditure were not changed over any of the diet interventions. Fasting serum glucose decreased during the MUFA and CHO diet periods compared with SAT diet (5.02±0.1, 5.03±0.1, 5.50±0.2mmol per L, respectively, ANOVA<0.05). The MUFA diet improved insulin sensitivity indicated by lower HOMA-IR, compared to CHO and SAT diets (2.32±0.3, 2.52±0.4, 2.72±0.4, respectively, ANOVA<0.01). Compared to a CHO breakfast, the AUC of postprandial glucose and insulin were lower with MUFA or SAT breakfasts (11.9±2.7, 7.8±1.3, 5.84±1.2mmol x 180minutes per L, ANOVA< 0.05; and 2,667±329, 1,004±147, 1,253±140, pmol x 180minutes per L, ANOVA<0.01, respectively). Integrated glucagon-like peptide-1 increased with MUFA and SAT breakfasts compared with isocaloric CHO breakfast. Fasting and postprandial HDL-C increased with MUFA diet and the AUC of TG decreased with CHO diet. Fasting proinsulin decreased, while stimulated ratio PI/I was not changed by MUFA diet. Overall, weight maintenance with a MUFA rich diet improves HOMA-IR and fasting proinsulin levels in IR subjects.

Rasmussen et al, 2006 (neutral quality) This was a randomized controlled, parallel, multi-center study. This trial investigated whether dietary MUFA, compared to SFA affects BP in healthy subjects (N=162, 76 women and 86 men) over a three-month period. A secondary purpose was to investigate if addition of long chain n-3 fatty acids would affect BP. Subjects followed one of two isoenergetic diets: One rich in MUFA (MUFA diet, 8%of energy as SFAs, 23% as MUFAs and 6% as PUFAs) and the other rich in SFA (SFA diet, 17% of energy as SFAs, 14% as MUFAs and 6% as PUFAs). Each group was further randomly assigned to receive supplementation with fish oil (3.6g n-3 fatty acids per day) or placebo. Adherence to the diets was not different between groups. Body weight remained unchanged during the studySystolic BP and diastolic BP (DBP) decreased with the MUFA diet [-2.2% (P=0.009) and -3.8% (P=0.0001), respectively], but did not change with the SFA diet [-1.0% (P=0.2084) and -1.1% (P=0.2116)]. The MUFA diet caused a significantly lower DBP than did the SFA diet (P=0.0475). The favorable effects of MUFA on DBP disappeared at a total fat intake above the median (>37% of energy). The addition of n-3 fatty acids influenced neither SBP nor DBP.

Tanasescu et al, 2004 (positive quality) This study used data from the prospective cohort Nurses' Health Study conducted in the US to assess the relationship between different types of dietary fat and cholesterol and the risk of CVD among women with T2D. The Nurses' Health Study started in 1986 with follow-up questionnaires sent every two years. Dietary fat and cholesterol were assessed through semi-quantitative food-frequency questionnaire (FFQ). Five thousand six hundred seventy two female nurses (30-55 years in 1976) who had reported a physician's diagnosis of diabetes at age >30 years on any follow-up questionnaire were included in the analysis. Between 1980-1998, 619 new cases of CVD (non-fatalMI, fatal CHD and stroke) were identified. Relative risks of CVD were estimated from Cox proportional hazards analysis after adjustment for potential confounders. The relative risk of CVD for an increase of 200mg cholesterol per 1,000kcal was 1.37 (95% CI: 1.12-1.68, P=0.003). Each 5% of energy intake from SFA, as compared with equivalent energy from CHO, was associated with a 29% greater risk of CVD (RR=1.29, 95% CI: 1.02-1.63, P=0.04). The PUFA: SFA (P:S) ratio was inversely associated with risk of fatal CVD. Replacement of 5% energy from SFA with equivalent energy from CHO or MUFA was associated with a 22% or 37% lower risk of CVD, respectively. Overall, an increased intake of cholesterol and SFA and a low P:S was related to increased CVD risk in women with T2D. Among women with T2D, replacement of SFA with MUFA may be more protective against CVD than replacement with CHOs.

Thijssen et al, 2005a (positive quality) **and Thijssen and Mensink, 2005b** (positive quality) This was a randomized multiple crossover study conducted in the Netherlands that compared the effects of fat types: Stearic, oleic (MUFA) and linoleic acids on platelet aggregation, coagulation, fibrinolysis and hematological variables in 45 healthy subjects (18 men and 27 women, mean age 51 years, range 28-66 years). Subjects consumed three test diets in random order over three five-week periods and after each intervention period, there was a washout period of at least one week when participants consumed their habitual diets. The test diets contained approximately 35% of energy from fat, and each diet contained 7% of energy as linoleic, stearic acid or oleic acid. Subjects visited a dietitian at least once every week to receive a new supply of products and to be weighed. Individual allowances were adjusted when subjects' weight differed by 1kg from the initial weight during week 1- or 2kg during the following weeks. Thijssen et al, 2005b found that in men (N=18), ex vivo platelet aggregation time as measured by filtragometry (P=0.036 for diet effects) was favorably prolonged during consumption of the PUFA diet compared with the stearic acid diet (P=0.040). No effect was found in women (N=27 After the high linoleic diet, the number of erythrocytes was lower and the mean platelet volume of the subjects decreased during consumption of the stearic acid diet by 0.32fL compared with the oleic acid diet (P<0.001) and by 0.35fL compared with the linoleic acid diet (P<0.001). The effects on coagulation and fibrinolytic variables did not differ among the other two fatty acids. Thijssen and Mensink, 2005b, found NS differences in serum LDL-C (P=0.137 for diet effects) or HDL-C (P=0.866). Very-low-density lipoprotein (VLDL) particle sizes and lipoprotein subclass distributions also did not differ significantly between the three diets. (abSame Study; two publications).

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Author, Year, Study Design, Class, Rating	Study Description, Duration	Study Population/ Location	Intervention Protocol/Exposure levels	Significant Results	Limitations
Allman-Farinelli et al 2005 Study Design: Randomized Crossover Trial Class: A Rating:	Randomized extra-period crossover trial. SFA diet for five weeks. MUFA diet for 10 weeks.	N=15 healthy men and women. Age: 35-69 years. Attrition: 17%. Location: Australia.	**SFA vs. MUFA** Two diets: • MUFA rich diet (high-oleic-acid sunflower oil) (Energy 32.6% total fat; 8.8% SFA; 20.3 % MUFA) • SFA rich diet (Energy 33.1% total fat; 20.8% SFA; 9.6% MUFA) No wash out.	Factor VII was lower with MUFA fat rich diet (P<0.05). **LDL-C (P<0.001) and TG (P<0.01)** lower on the MUFA diet. MUFA diet ↑ plasma PL and neutral lipid oleic acid (P<0.0001). Fibrinogen, plasminogen activator inhibitor-1, insulin concentration did not between diets.	Small number of subjects. No washout periods.
Appel LJ et al 2005 Study Design: Randomized Crossover Trial Class: A Rating:	OmniHeart. Compared the effects of three diets, for six weeks each. Washout period of two to four weeks separated the feeding periods.	N=191, healthy adults with Stage I HTN or PHTN. Mean age: 53.6 years. Attrition: ~15%. • N=191 randomly assigned • N=164 completed two feeding periods; N=159 completed all three diet periods • N=161 included in the analysis (45% women). Location: United States.	Unsaturated fat (MUFA) vs. CHO diet. Compared the effects of three diets, each with 6% energy from SFA, on BP and serum lipids. Percent energy: • CHO-rich diet: 58% CHO, 15% PRO, 27% total fat (13% MUFA) • Protein-rich diet: 48% CHO, 25% PRO, 27% total fat (13% MUFA) • Unsaturated fat (MUFA) rich diet: 48% CHO, 15% PRO, 37% total fat (21% MUFA) All diets were (per day): <150mg cholesterol, >30g fiber, 2,300mg Na, 4,700mg K, 500mg Mg, 1,200mg Ca.	**Unsaturated fat vs. MUFA vs. CHO diet:** ↓ **SBP** 1.3mmHg (P=0.005); 2.9mmHg in HTN subjects (P=0.02; NS effect on LDL-C; ↑ HDL-C 1.1mg per dL (0.03mmol per L; P=0.03); ↓ TG 9.6mg per dL (0.11mmol per L; P=0.02). **PRO vs. CHO** Protein diet: ↓ mean SBP 1.4mmHg (P=0.002); 3.5mmHg (P=0.006) in HTN subjects; ↓ LDL-C 3.3mg per dL (0.09mmol per L; P=0.01); HDL-C 1.3mg per dL (0.03mmol per L; P=0.02); TG 15.7mg per dL (0.18mmol per L; P=0.001).	None.

Berglund L, Lefevre M et al, 2007 Study Design: Randomized Crossover Trial Class: A Rating:	Three diets fed in a double-blind, three-way crossover with each diet lasting seven weeks. Rest period of four to six weeks between each diet.	N=85, high metabolic risk profile (33 females, 52 males). Attrition: 23%. Mean age: 35.5±9.2 years (range 21-61 years); three diets. Location: United States.	Compared **MUFA** with **CHO** as a replacement for **SFA**. **Three diets:** • Average American diet (**AAD**; reflecting the typical pattern of the US population) • **CHO**-replacement diet (meeting the nutrient specifications of the NCEP Step I diet) • **MUFA** fat-replacement diet (to match the SFA and PUFA content of the CHO-replacement diet, but also the total fat of the AAD;**36% energy from fat**) **7% energy from SFA replaced** with either CHO (primarily complex) on the CHO-replacement diet or with MUFA on the MUFA-replacement diet. All food was provided except for a self-selected meal (following the NCEP Step I guidelines) on Saturday evenings. Blood samples were drawn at weeks five, six and seven of each of the three diets.	Relative to **AAD**: **LDL-C** was lower with CHO (-7.0%) and MUFA (-6.3%) diets, compared to AAD. **HDL-C** differences were ↓ for MUFA (-4.3%) than CHO diet (-7.2%). **Lipoprotein (a)** concentration ↑ with both CHO (20%) and **MUFA** (11%) diets, relative to AAD.	Weights were maintained, so the issue of dietary effects on lipid concentrations under "free-living" conditions is unknown.
Binkoski AE et al 2005 Study Design: Randomized crossover trial. Class: A Rating:	Subjects were randomized to each diet for four-weeks. Two-week washout period.	N=31 subjects with moderate hypercholesterolemia (12 men, 19 women) Age: 25-64 years.	**MUFA** vs. NuSun sunflower oil **Two test diets:** • 30% fat as olive oil • NuSun sunflower oil contributing one-half of the fat (8.3% vs. **7.9% SFA**, 17.2% vs. **14.2% MUFA** and 4.3% vs. **7.7% PUFA**, respectively). **Third diet** (control): Average American diet (ADD) (34% fat; 11.2% SFA; 14.9% MUFA; 7.8% PUFA).	Only the sunflower oil diet ↓ both TC and **LDL-C** levels compared with the other two diets; TC ↓ 4.7% and LDL-C ↓ 5.8% on the sunflower oil diet compared to the ADD. The experimental diets had **no effect on** TG levels, rate of oxidation, total dienes, lipid hydroperoxides or alpha-tocopherol.	Relatively small sample size. AAD not well-defined. Sponsored by the National Sunflower Association.
Clifton PM, Noakes M et al, 2004 Study Design: Randomized Controlled Trial Class: A Rating:	12-week parallel design study.	N=62 women with BMI>27kg/m^2 without diabetes. Mean age: Years±SD • Very low fat: 46.9±9.9 • H-MUFA: 47.1±10.7. Location: United States.	**MUFA vs. CHO** [both in low SFA compared to baseline] Random assignment to one of two 6,000kJ diets (%energy): • **High MUFA:** (35% fat, **20% MUFA**) • Very low-fat diet (VLF): 12% fat, 4% MUFA).	**Δ in weight, LDL-C, TG, HDL/LDL ratio, BP and blood glucose did not differ between diets.**	Short duration.
Due A et al 2008 Study Design: Randomized Controlled Trial Class: A	Duration: Six months.	N=169. Attrition: N=131 (55 males, 76 women); 25 did not complete the six-month intervention. Age: 18-35 years (28.2± 4.8 years).	**Three diets:** • Moderate fat and >20% MUFA diet, N=54, low GI and 10-20% PRO • 20-30% kcals from fat; low-fat (LF diet, N=51), moderate GI and 10-20% PRO	Diet composition did not have major effects on maintenance of weight loss during the six-month dietary intervention. The MUFA and LF diets had slower rates of weight gain when compared to a Western diet. The MUFA diet may have a	Other lifestyle factors besides diet may help with obesity prevention and weight maintenance.

Rating:		BMI: 28-36kg/m^2. Location: Copenhagen, Denmark.	• Control diet, 5% kcals from fat (N=26), high GI, 10-20% PRO three-week run-in diet.	positive impact on diabetes risk factors. The type of diet followed may not matter as it relates to weight loss maintenance. The type of dietary fat may affect body fat composition and satiety. The MUFA diet ↓ fasting insulin and improved HOMA-IR. A diet ↑ in unsaturated fat may improve insulin resistance.	
Jakobsen MU, O'Reilly EJ et al, 2009 Study Design: Meta-analysis or Systematic Review Class: M Rating:		N= 344,696 subjects. Pooled from 11 American and European cohort studies published between 1966 and 1993.	Data Analyisis. Incidents of CHD associated with energy intake from MUFA, PUFA and CHO and risk of CHD.	Follow-up: Four to 10 years 5,249 coronary events; 2,155 coronary deaths. Significant inverse associations found for PUFA or CHO as replacement sources for 5% lower energy from SFAs and risk of coronary events reported as HR for: PUFA: HR=0.87 (95% CI: 0.77, 0.97); HR for coronary deaths=+0.74 (95% CI: 0.61, 0.89). CHO: HR=1.07 (95% CI: 1.01, 1.14); HR for coronary deaths=0.96 (95% CI: 0.82, 1.13). **MUFA** intake was not associated with CHD.	The country and demographics of subjects not described.
Lopez S, Bermudez B et al, 2008 Study Design: Randomized Crossover Trial Class: A Rating:		N=14 men; healthy normotriglyceridemic with normal glucose tolerance. Mean age: 27 years. Mean BMI: 23.9kg/m^2. Location: Spain.	Four isocaloric diets with 9% ↑ fat [replacing CHO in Step I diet as control] 1. Control Step I 2. High butter (MUFA:SFA, 0.48:1.0) 3. Refined olive oil (ROO) (MUFA:SFA, 5.43:1.0) 4. High palmitic sunflower oil (HPSO) (MUFA:SFA, 2.42:1.0) 5. Mixture of vegetable and fish oils (VEFO) (MUFA:SFA, 7.08:1.0).	**High fat meals:** • ↑ postprandial insulin, TG and FFAs • ↑ pancreatic beta-cell activity • ↓ insulin sensitivity. Postprandial insulin sensitivity ↑ and as proportion of MUFAs, (vs. SFAs) ↑: VEFO>ROO>HPSO>Butter. Beta-cell activity, measured as early postprandial insulin response, ↓ as proportion of MUFAs (vs. SFAs) ↑.	Relatively low subject number (N=14).
Paniagua JA, de la Sacristana AG et al, 2007 Study Design: Prospective Cohort Study Class: B Rating:	Randomized cross-over 28-day feeding trial.	N=11 (four men, seven women). Age: 62±9.4 years. Insulin resistant by OGTT. Location: Spain.	Three isocaloric diets (% energy): 38% fat and 47% CHO. In two high fat diets (% energy): 23% SFA or MUFA; 20% fat; 65% CHO in the low-fat diet (replacement of SFA).	**SFA vs. MUFA:-** ↑ HBA1c (P<0.01), ↑ fasting glucose by 9.6%- (P<0.05), ↑ HOMA by 17.2% (P<0.01), ↑ fasting proinsulin by 26.1% (P<0.05), NS effects on postprandial glucose, postprandial insulin or postprandial GLP-1 **SFA vs. CHO:-** ↑ HBA1c by 6.3% (P<0.01), ↑ fasting glucose by 9.3% (P<0.05), ↓ postprandial glucose by 51 (P<0.05), ↓ postprandial insulin by 53	None.

				(P<0.05), ↑ postprandial GLP-1 by 134.6 (P<0.05). NS effects on HOMA or fasting proinsulin. NS effects on fasting insulin or GLP1, or the 60 minutes proinsulin:insulin ratio with any diet.	
Rasmussen BM, Vessby B et al, 2006 Study Design: Randomized controlled trial; parallel, multi-center study Class: A Rating:	KANWU Study.	N=162 (95 men and 67 women). Healthy population. Attrition:162 because of intent to treat analysis. Three dropped out. Age: • 30 to 65 years • SFA/placebo group (N=42): 49.3±7.1 (mean±SD) • SFA/n-3 FA group (N=41): 48.5±8.0 • MUFA/placebo group (N=40): 47.0±8.8 • MUFA/n-3 FA group (N=39): 49.5±7.3. Location: Denmark.	Isoenergetic diets with the same amount of macronurients consumed for three months. 37% kcal from fat was used for both the high-MUFA and the high-SFA diets. MUFA diet: 8% kcal from SFA; 23% from MUFA; 6% from PUFA. SFA diet: 17% kcal SFA; 14% from MUFA; 6% from PUFA. Randomized subgroups from the MUFA group and from the SFA group received additional fish oil capsules with 3.6g n-3 fatty acids per day (2.4g as EPA and DHA). Trained dietitians instructed all subject on preparation of their diets and met with subjects at least every other week until the end of the study. Edible fats supplied to use as spreads, for cooking and in dressings that contained neglible amounts of TFAs, n-3 FAs or olive oil.	A significant ↓ from baseline in SBP for the MUFA treated group (-2.2%; P=0.009) and for DBP (-3.8%; P=0.0001) without significant Δ for the SFA diet group. MUFA diet caused lower DBP than the SFA diet (P=0.0475). Above shows the Δ from baseline with the added covariate of < or >37% of total kcals as fat. When total fat was <37%, the MUFA diet ↓ SBP and DBP. These differences disappeared when fat intake was >37% of kcals. There was no effect of added n-3 FAs.	Double-blinding was not used. Weight, exercise and smoking habits were kept stable for the duration of the study. Compliance was checked by diet records and serum phospholipid fatty acid composition. There was a slightly ↑ dietary fiber intake and ↓ cholesterol intake by the MUFA group. There was no difference in calculated dietary intakes of Ca, Na, K and alcohol between the groups.
Tanasescu et al 2004 Study Design: Prospective Cohort Study Class: B Rating:		N=5, 672 female nurses. Age: 30-55 years in 1976. Reported a physician's diagnosis of diabetes at age >30 years. Location: United States.	Dietary fat and cholesterol assessed by semi-quantitative FFQ. Estimated the effects of isocaloric (5% energy as fat) substitution of CHO or MUFA for SFA from the multivariate model including SFA, PUFA, MUFA, TFA, cholesterol, PRO, total calories, fiber and non-dietary covariates.	619 new cases of CVD (nonfatal MI, fatal CHD and stroke) were identified between 1980 and 1998 (57,195 person-years). The P:S ratio (PUFA to SFA) was inversely associated with risk of fatal CVD. Replacement of 5% energy from SFA with equivalent energy from MUFA was associated with 37% lower risk of CVD.	None.
Thijssen et al 2005 Study Design: Randomized Crossover Trial Class: A Rating:	Three test diets consumed over three five-week periods. Washout period of at least one week between diets.	N=45 healthy subjects (18 men; 27 women). Mean age: 51 years (range 28-66 years). All subjects were assumed to have completed the trial. Location: The Netherlands.	Compared the effects of stearic, oleic and linoleic acids on platelet aggregation, coagulation, fibrinolysis and hematological variables. Three-test diets in random order over three five-week periods. Test diets contained ~35% energy from fat and each diet contained 7% energy as either stearic acid, oleic acid or linoleic acid. After each intervention period, there was a washout period of	After the high linoleic acid diet, the number of erythrocytes was lower and ex vivo platelet aggregation was favorably prolonged compared to the stearic acid diet. Stearic acid consumption reduced platelet volume compared to the other two fatty acids (P<0.001). The effects on coagulation and fibrinolytic variables did not differ among the three fatty acids.	Recruitment methods for subjects are described elsewhere. Handling of withdrawals not discussed. Sponsored by the Dutch Dairy Association.

			there was a washout period of at least one week when participants consumed their habitual diets.		
Thijssen MA and Mensink RP, 2005 Study Design: Randomized Controlled Trial Class: A Rating:	Four to five weeks.	N=45 (18 males, 27 females). Healthy non-smoker adults, slightly hypercholesterolemic. Age: 28-66 years (mean 51 years). Location: The Netherlands.	**Compare the effects of stearic, oleic and linoleic acids on platelet aggregation, coagulation, fibrinolysis and hematological variables.** Each participant consumed three different diets in random order over three five-week periods. After each intervention period, there was a washout period of at least one week when participants consumed their habitual diets. Three diets, each diet contained 7% energy from stearic acid, oleic acid or linoleic acid. The diets contained ~35% energy from fat.	Ex vivo platelet aggregation time favorably prolonged (P=0.036 for diet effects) on linoleic acid diet compared with the stearic acid diet (P=0.040); no difference with oleic acid diet (P=0.198). In vitro platelet aggregation induced by collagen and ADP, and variables of coagulation and fibrinolysis did not differ between the diets. Hct values were slightly lower in men on linoleic acid diet compared to diets high in stearic acid and oleic acid. Platelet volume ↓ by 0.32fL on the stearic aid diet, compared with the oleic acid diet (P<0.001) and by 0.35fL compared with the linoleic acid diet (P<0.001).	None.

Research Design and Implementation Rating Summary
For a summary of the Research Design and Implementation Rating results, click here.

Worksheets

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